LAND DISPOSAL OF LAGOON EFFLUENT AT SHELBURNE

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LAND DISPOSAL OF
LAGOON EFFLUENT
AT SHELBURNE

By

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Research Branch
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ABSTRACT

Several processes of land disposal of lagoon effluent have been investigated in many different countries. Because land and weather conditions vary, it becomes necessary to determine the suitability of each geological area for a spray irrigation program.

The Research Branch, Ministry of the Environment initiated studies on a spray irrigation program in the Spring of 1971 to determine the feasibility of such a program in Ontario and to provide guidelines for operation.

Spraying was carried out over two summer and fall seasons in 1971 and 1972 with no serious effects on land or groundwater quality. The amount of effluent which was sprayed depended on soil permeability and weather conditions.

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Mr. R. Pugh, Technologist.
Mrs. Maria Schouten, Technologist.
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1.0 INTRODUCTION

The increased emphasis on reducing the nutrient loading, primarily phosphorus and nitrogen, from sewage treatment plants has prompted various investigations into controlling the effluent nutrients from waste stabilization ponds (WSP). As part of this investigation a study of disposal of sewage and sewage effluents on land was initiated.

Reports indicated that spray disposal of sewage treatment plant effluent on suitable land produced an effluent percolate that had no adverse effects when recharged to the groundwater reservoir.

Land disposal of effluent as a means of avoiding discharge into public water courses is not a new concept in Ontario. Papers presented during several Ontario Industrial Waste Conferences describe the disposal of dairy, tannery, cannery and pulp mill wastes. (1)

Although most efforts were successful, a special investigation carried out by the Ontario Water Resources Commission, Division of Water Resources, indicated that over a long period of operation ground water contamination could occur. (2)

Land disposal of effluent from domestic waste stabilization ponds is in operation on a small scale in resort areas where ponds are filled in the summer and the effluent is sprayed in the fall or the following spring. Land is usually available in the form of adjacent fields or treed areas and is far enough from populated areas to eliminate any direct health hazard.

In the case of land disposal of effluent, the soil, in combination with the vegetation, provides treatment of the wastewater through evapotranspiration, adsorption, chemical precipitation, ionic exchange, biochemical transformation and biological adsorption, with the treated effluent recharged to the ground reservoir. (3)

The object of land disposal of effluent is to apply the maximum amount of water a given soil can absorb without causing clogging of the soil, surface run-off, contamination of the groundwater or damage to the vegetation. (4) Lagoon effluent contains several valuable plant nutrients in varying quantities which under good crop and soil management may provide a source of fertilization for farm crops not intended for human consumption.

The disposal of sewage effluent on land may cause several problems as some of the constituents which may be present in wastewater can damage the soil, vegetation and potable ground water supply. Although copper, zinc and other heavy metals are absorbed by soils, their salts in certain concentrations are toxic to plants. Chlorides are not adsorbed by soils and can percolate into the groundwater, while nitrogen movement through the soil is well documented and would be expected particularly below the biologically active zone and the saturated zone.

Waste stabilization ponds used in connection with a spray irrigation system are being designed as sewage treatment facilities for several small communities in Ontario. To date the allowable design rate for spraying has been 56 m^3/ha/day (5000 IG/acre/day) or 3.8 cm/week (1.5 inches/week). Since the wastewater flow is a continuous one, waste stabilization ponds become storage reservoirs from which the effluent is sprayed on suitable days of the year.

The purpose of this study was:

(a) to establish criteria for maximum spraying rates of effluent (m^3/ha/day or cm/week).

(b) to gather information on the treatment capacity of the soil and the possible contamination of groundwater.

(c) to evaluate the effect on unmanaged crops.

(d) to investigate any physical side-effects as a result of spraying of waste stabilization pond effluent.

2.0 GENERAL

The Village of Shelburne (population 1500) is located at the junction of Highways 10 and 89 at the geographic centre of Dufferin County, Ontario. The village functions as a residential and farming community centre with no industry except for one feedmill.

Sewage treatment is provided by a 5.33 hectare (13.5 ac) continuous overflow waste stabilization pond (lagoons) consisting of two 2.66 ha (6.58 ac) cells operated in parallel and designed to serve 1,350 people. Average flow to both cells during the period covered by this report was 837 m^3 per day (0.184 MIGPD) with a 5-day Biochemical Oxygen Demand (BOD) loading of 25.5 kg/ha/day (22.7 lbs/ac/day). Average total phosphorus concentration in the influent was 12.2 milligrams per litre (mg/l). Effluent from the WSP was discharged to, and comprises the bulk of the flow of a small tributary of the Boyne River which empties into Georgian Bay. Average effluent BOD from the Shelburne WSP during the study period was 40 mg/l.

The Shelburne lagoon site is shown in Figure 1. The land used for irrigation was adjacent to the lagoons and owned by the Municipality, and is approximately 4 ha (10 acres) in area, of which 3.2 ha (8 acres) has a twitch grass cover and 0.8 ha (2 acres) is a treed area with heavy groundcover.

The wastewater is domestic only and the effluent from the west cell was used for spraying. Averages of chemical constituents in the effluent during spraying periods are given in Table 1. The average inflow into the west cell during the period of the study was 429 m^3/day (0.094 MIGPD).

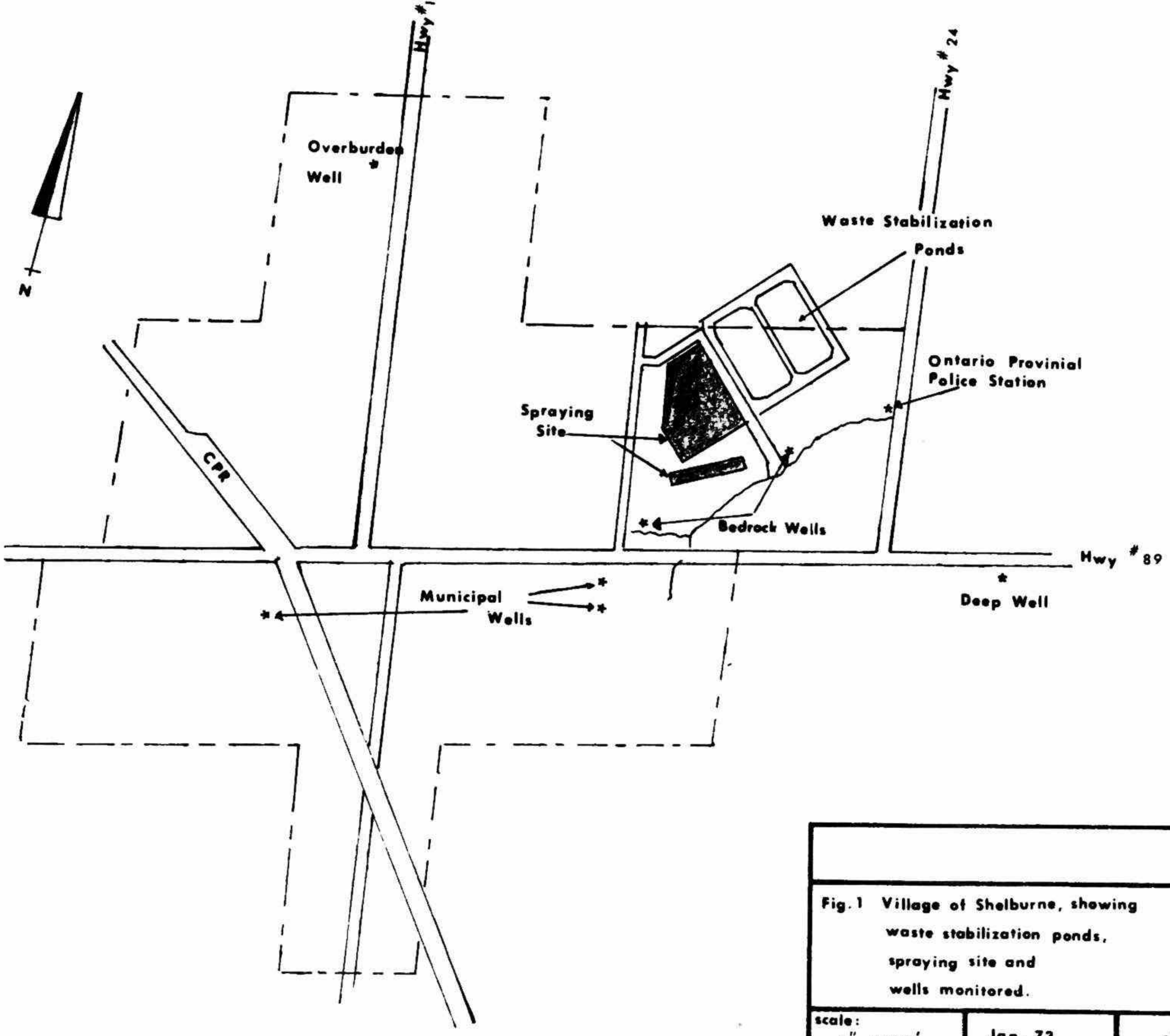

Fig. 1 Village of Shelburne, showing waste stabilization ponds, spraying site and wells monitored.

scale: 1" = 1200'	Jan. 73	rfp

TABLE 1

CHEMICAL CONSTITUENTS IN THE EFFLUENT OF THE WEST WASTE STABILIZATION POND DURING SPRAYING PERIODS.
(AVERAGE FIGURES, IN mg/l EXCEPT FOR pH)

	1971	1972
Phosphorus, as P		
Total	4.1	3.8
Soluble	2.9	1.8
Nitrogen, as N		
Free Ammonia	3.0	2.2
Total Kjeldahl	9.2	10.7
NO_2	.20	.10
NO_3	.25	.14
Solids		
Total	630	610
Suspended	60	70
Dissolved	570	540
Chlorides, as Cl	75	79
Sodium, as Na	67	53
Potassium, as K	11.0	10.7
Magnesium, as Mg	30.0	28
Manganese, as Mn	.16	.04
Iron, as Fe	.28	.30
Sulphates, as SO_4	57	81
Alkalinity, as $CaCO_3$	287	258
Hardness, as $CaCO_3$	326	293
BOD	43.0	40.0
pH	8.2	8.7

3.0 SITE CHARACTERISTICS

3.1 Physiography

Shelburne is located on the Dundalk Till Plain, surrounded by a complex of glacial spillways, fluted till plains, kames and till moraines. The topography is generally undulating. Two types of soil are predominant: a) Honeywood soils, well drained, that have developed on wind-deposited silt loam or fine sandy loam materials underlain by calcareous loam till; b) Tuscola silt loam, imperfectly drained, developed from calcarious water-lain fine sands and silts.

3.2 Bedrock

The bedrock in the area is grey and blue-grey medium crystalline dolomite of the Amabil Group of formations. It is highly fractured and easily recharged by percolating groundwater. The bedrock in this area is one of the best aquifers in Ontario.

The municipal wells, two bedrock wells, are approximately 360 m (1200 feet) from the spraying site. A pumping test was carried out to determine the influence of the municipal wells on the aquifer in the vicinity of the spray area, using the monitoring facilities installed on and around the site. The pumping test showed that the natural gradient of the bedrock piezometric surface is towards the municipal wells.

3.3 Overburden

The overburden at the spraying site is approximately 13 meters deep (40 feet) and consists of a sandy till. The direction of the surface drainage in the areas is towards the northeast. There are few overburden wells in the area; the majority being bedrock wells. The overburden piezometric surface is sloped away from the municipal wells. No hydraulic connection between the overburden and bedrock aquifer was observed.

3.4 Soil Characteristics

The soils at the spraying site were mapped for suitability by Professor L.R. Webber of the University of Guelph. Soil in the grassed area consists of a well drained, fine sandy loam with moderate permeability of 1.5 - 4.0 cm per hour (0.6 - 1.5 inches per hour). Maximum water retained under field conditions for the first 1.2 m (4 feet) was approximately 23 cm (9 inches). The land itself is slightly undulating and the groundwater table is approximately 1.5 m - 2.4 m (5-8 feet) below the surface.

The soil in the treed area has poorer draining characteristics and the water table is approximately 0.5 m (1.7 feet) below the surface. The area was used for a low rate of application to evaluate the effects of spraying on the trees, mainly cedar, and ground cover.

The spray site at Shelburne is in an open field, except for the treed area to the south of the site. This allows the wind to play a large role in the evaporation process. The average temperature during the spraying months was approximately $18^{o}C$ ($65^{o}F$) while rainfall was light to moderate. Table 2 shows a summary of weather conditions as recorded from the Redickville Weather Station, a few miles north of Shelburne.

TABLE 2

ANNUAL TEMPERATURE AND PRECIPITION

ABSTRACT FOR SHELBURNE AREA

	TEMPERATURE						Precipitation		Evaporation	
	Max.		Min.		Mean					
	°F	°C	°F	°C	°F	°C	cm	in	cm	in
Jan.	22	-5.6	6	-14.4	14	-10.0	8.96	3.53	0	0
Feb.	24	-4.4	7	-13.9	15	- 9.4	7.80	3.07	0	0
Mar.	32	0	17	-8.3	24	- 4.4	9.01	3.55	0	0
Apr.	51	10.6	32	0	41	5.0	7.45	3.05	5	2
May	61	16.1	41	5.0	51	10.6	7.60	2.99	11	4.5
June	70	21.1	49	9.4	60	15.6	7.46	2.94	14	5.5
July	75	23.9	55	12.8	65	18.3	7.44	2.93	15	6
August	75	23.9	54	12.2	65	18.3	8.33	3.28	11	4.5
Sept.	67	19.4	49	9.4	58	14.4	7.46	2.94	8	3
Oct.	55	12.8	39	3.9	47	8.3	7.57	2.98	5	2
Nov.	39	3.9	29	-1.7	34	1.1	9.65	3.80	2	1
Dec.	32	0	19	-7.2	26	-3.3	8.35	3.29	0	0

Precipitation and Temperature figures from Redickville Station. Evaporation figures from climatic maps of Canada.

4.0 DESIGN OF THE SPRAY SYSTEM

4.1 Equipment

A 10 cm (4") aluminum main was run from the west lagoon overflow manhole into the adjacent field, which was evenly divided into two 1.6 ha (4 acre) plots designated areas A and B. Each plot contained 30 sprinklers connected to 5 cm (2") polyethylene laterals.

A 10 cm (4") polyethylene branch from the aluminum main supplied effluent to a 7.5 cm (3") lateral running parallel to the edge of the 0.8 ha (2 acre) treed area, area C. Soaker hoses connected to the lateral were placed between the trees. Figure 2 shows the irrigation system and sprinkler pattern.

An electric centrifugal pump with capacity of 728 liters per minute (160 IGPM) at 45 m (150 feet) head pumped the effluent from the cell to the spray area. The effluent was not screened. A magnetic flow recorder was installed in the aluminum main immediately after the bypass.

4.2 Spraying Rates

With the bypass valve slightly open, the flow to areas A and B was 525 l/min (115 IGM). Each sprinkler covered an approximate 21 m (70 ft.) circle with no overlap. From these figures, the sprinkler application rate in areas A and B was determined to be 0.3 cm/hr (0.12 inches/hr). At a flowrate of 205 litres/min, the application rate in the treed area (C) was 0.08 cm/hr (0.03 inches/hr). Tables 3a and 3b show the

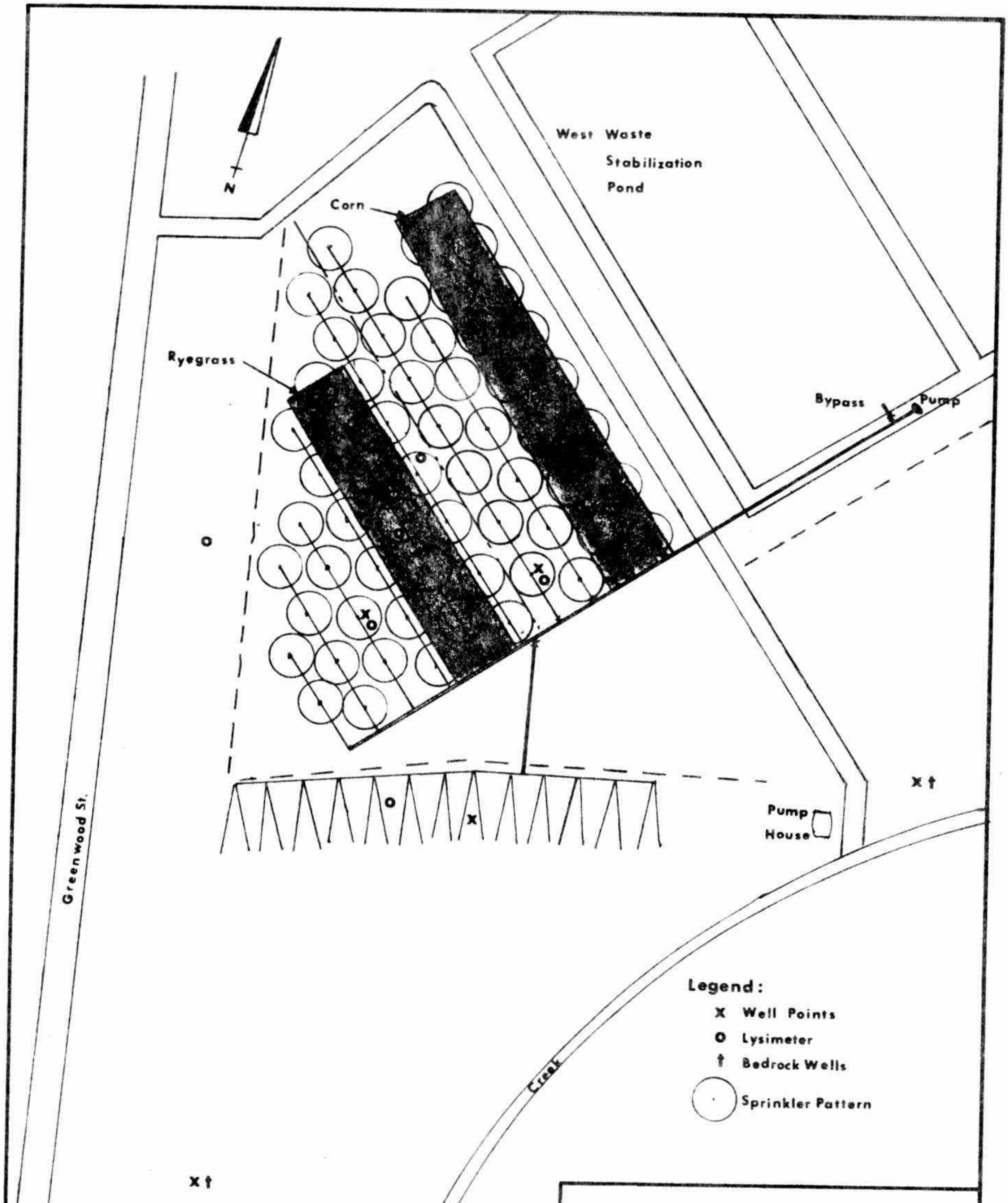

Fig. 2 Sprinkler System and Location of Monitoring Sites.

spraying rates for the two periods of operation in 1971 and 1972, respectively.

4.3 Spraying Program

In 1971 spraying program was planned as follows:

Area A, grasscover, 10 cm (4") per week -
high rate area.

Area B, grasscover, 5 cm (2") per week -
low rates area.

Area C, treed approximately 2.5 (1") per week.

The 1972 spraying program remained the same, but approximately 0.4 ha (1 acre) of corn was planted in area A and approximately 0.4 ha (1 acre) of rye-grass in area B.

No one area was sprayed on consecutive days to allow the soil a recovery period.

TABLE 3a

SPRAY SUMMARY FOR SHELBURNE, 1971

AREA	MONTH	SPRAY		RAINFALL		TOTAL PRECIPITATION		POTENTIAL EVAPORATION	
		in/wk	cm/wk	in/wk	cm/wk	in/wk	cm/wk	in/wk	cm/wk
A	August	2.15	5.47	.87	2.20	3.02	7.67	1.45	3.69
	September	3.01	7.66	.20	.51	3.21	8.17	.82	2.09
	October	1.34	3.40	.34	.85	1.68	4.25	.56	1.42
B	August	1.80	4.57	.87	2.20	2.67	6.77	1.45	3.69
	September	1.86	4.72	.20	.51	2.06	5.23	.82	2.09
	October	1.28	3.24	.34	.85	1.62	4.09	.56	1.42
C	August	.18	.45	.87	2.20	1.05	2.65	1.45	3.69
	September	.27	.68	.20	.51	.47	1.19	.82	2.09
	October	.27	.69	.34	.85	.61	1.54	.56	1.42

Note: TOTAL PRECIPITATION - POTENTIAL EVAPORATION = MINIMUM NET PRECIPITATION.

TABLE 3b

SPRAY SUMMARY FOR SHELBURNE, 1972

AREA	MONTH	SPRAY		RAINFALL		TOTAL PRECIPITATION		POTENTIAL EVAPORATION	
		in/hr	cm/hr	in/hr	cm/hr	in/hr	cm/hr	in/hr	cm/hr
A	June	.13	.32	.93	2.36	1.06	2.68	1.26	3.20
	July	.63	1.59	.52	1.33	1.15	2.92	1.56	3.96
	August	.96	2.43	.43	1.09	1.39	3.52	1.21	3.09
	September	2.76	7.02	.31	.78	3.07	7.80	.70	1.78
B	June	.26	.66	.93	2.36	1.19	3.02	1.26	3.20
	July	1.28	3.26	.52	1.33	1.80	4.59	1.56	3.96
	August	1.12	2.84	.43	1.09	1.55	3.93	1.21	3.09
	September	1.92	4.97	.31	.78	2.23	5.75	.70	1.78
C	June	.03	.08	.93	2.36	.96	2.44	1.26	3.20
	July	.16	.41	.52	1.33	.68	1.74	1.56	3.96
	August	0	0	.43	1.09	.43	1.09	1.21	3.09
	September	.06	.16	.31	.78	.37	.94	.70	1.78

NOTE: TOTAL PRECIPITATION - POTENTIAL EVAPORATION = MINIMUM NET PRECIPITATION.

5.0 MONITORING PROGRAM

An extensive monitoring program was initiated to check for possible contamination of groundwater and damage to the soil as a result of spraying.

A regular sampling program was carried out from March 1971 to October 1972. The effluent, several sections of the creek into which the effluent discharged, wells, well points and lysimeters were sampled and tested for chemical constituents, bacteriological quality and the presence of virus.

In order to forewarn of any microbiological contamination of the groundwater, two bedrock monitor wells were installed, one on the south side of the waste stabilization ponds and one between the municipal well and the spraying site; private wells in the vicinity were also protected by this arrangement. Pumping tests were carried out which showed that the monitor well between the spraying site and the municipal well was affected by draw down of the municipal well.

Five well points were installed to measure the depth of the groundwater table below the surface and to provide sampling points for groundwater. One was placed in each of the spray areas and one near each bedrock monitor well.

To evaluate the efficiency of the soil in removing chemical constituents, such as nitrogen and phosphorus, present in the effluent, lysimeters were installed. In 1971 each grassed area had four lysimeters at 15 cm, 30 cm, 60 cm, 120 cm (6", 1', 2', 3') below the surface. The treed area had a surface lysimeter at 15 cm (6"). In 1972, two additional surface lysimeters were installed, one in the rye-grass and one in the twitchgrass. A set of control lysimeters was installed west of the site. The location of wells, well points and lysimeters are shown in Figure 2.

Chemical tests for nitrogen, phosphorus, solids, chloride, potassium, sodium and pH, were done routinely and extra analyses were done when appropriate.

Since little information is available on the migration of microbial pathogens in soils and groundwaters under field conditions, this aspect was investigated.

Lagoon effluent was checked weekly for the presence of enteric viruses, E coli B bacteriophage, Salmonellae, coliforms and fecal coliforms. Samples from wells and groundwater were tested for E coli B bacteriophage, Salmonellae, coliforms and fecal coliforms, as were soil samples and vegetation cuts. The municipal and OPP wells were monitored weekly for enteric viruses. Prior to spraying, all monitoring wells were negative for these microorganisms.

A rain gauge was installed on the site to measure the rainfall in the area. Evaporation data was supplied by Atmospheric Environment Service at the Elora Station near Shelburne.

6.0 OPERATIONS

Installation of spraying equipment was completed by the end of July 1971 and spraying began immediately. All monitoring equipment had been installed by this time, except for the well points which were installed during August 1971.

During the warm months of August and September, 1971, the soil showed no effects due to the spraying program, but with the beginning of the cold weather in October, the soil became saturated and the spraying was reduced to avoid ponding. Heavy rainfall at times necessitated the shut-down of spraying operations to allow the soil to recover from the heavy loading. No changes were noticed in the ground water level except for a small rise in the forest area.

Operations were shut down in November and the pipes were drained and left in the field over the winter. During this time, a sampling programme was carried out to trace the possible after effects of the previous summer's spraying. Spraying equipment was re-installed by June 1972, but the program was seriously impeded till mid-August, due to a late spring thaw, heavy rainfall, and construction in the spraying area.

As mentioned in Section 4.3 corn was planted in a 0.4 ha (1 acre) plot in the high rate area and rye-grass was planted in a 0.4 ha (1 acre) plot in the low rate area during June. No attempt was made to manage these crops. Two new surface lysimeters were installed, one in the rye-grass and one in the twitch grass cover; the lysimeter pits used the previous summer had collapsed during the early spring and were abandoned.

Again by late September 1972, cold weather did not allow the soil time enough to recover under the original spraying program and ponding occurred in some of the low lying areas of the field in the high rate section. Frost and freezing conditions early in October forced the project to be terminated. The groundwater table varied erratically during this second season.

The polyethylene piping is sensitive to temperature changes and was allowed to move freely. Few sprinklers became clogged during the two summers of spraying. The soaking hoses in the forest were free from clogging, but undergrowth in the forest grew quickly making it necessary to remove the lines and lay them on top of the undergrowth at least three times during the experiment.

The lysimeters did not all yield sufficient percolate for groundwater samples. In the high rate area only from the surface lysimeter and in the low rate from the surface and the deepest (120 cm) lysimeter, could suitable samples be obtained. The control lysimeters did not receive enough rainfall for regular sampling. No samples were obtained from the lysimeter in the treed area.

7.0 RESULTS AND DISCUSSION

7.1 Wastewater Disposal

7.1.1 Volume of Effluent Sprayed

The total volume of effluent sprayed in 28 weeks of operation, was 24.9 x 10^3 m^3 (5.49 MIG) over the 4 ha (10 acre) site. This represented an average rate of approximately 32 m^3/ha/day (2,800 IG/ac/day) or 2.2 cm/wk (0.87 in/wk). Appendix I shows the volumes of wastewater sprayed on each area.

7.1.2 Chemical Constituents

The average weekly applications of chemicals to the 10 acre site were 9.2 kg (20.2 lb) nitrogen, 3.5 kg (7.8 lb) phosphorus, 9.7 kg (2.14 lb) potassium, 37 kg (81.5 lb) BOD and 68.5 kg (151 lb) chlorides. Appendix I shows a breakdown of chemicals applied on each area.

Table IV gives the concentration and percent removal of plant nutrients in the percolates; Table V shows the results of soil analysis for salts and metals after spraying had been stopped.

Free ammonia was effectively removed in all areas except the twitch grass, where a removal of only 64% free ammonia was achieved. The twitch grass lysimeter showed an extremely high increase in nitrate concentration in the low rate area at the 120 cm depth.

All monitor wells and well point samples showed very little change in nitrogen concentration.

In the first season of spraying, total phosphorus removal as calculated from lysimeter percolates, averaged 95% for all areas, while reduction dropped to an average of 84% during the second season. Soil samples analysed by the Department of Land Resource Science, Ontario Agricultural College (OAC), at the University of Guelph, after each season of spraying, showed that the phosphorus content of the soil was low and did not change significantly after the application of over five million gallons of effluent.

Potassium reduction in the percolates was greatest at the low rate, 120 cm level, at 84%, while the high rate and low rate area reductions at the surface, were 17% and 53% respectively. No results were obtained for potassium in the rye and twitch grass areas.

Potassium levels in soil taken after the first season of spraying showed "low" ratings (as defined by OAC) for the low rate spray area and the control plot, and a medium rating for the high rate area. After the second season of spraying, the potassium level in the low rate area jumped from a low rating of 60 mg/l to a high rating of 153 mg/l, while that in the high rate area remained essentially unchanged.

Chloride ions travel through most soils with less resistance than most other ions but practically no migration of these ions was observed in the groundwater at the Shelburne spraying site. Tests for chlorides on the well point samples showed a slight change in the low rate area, where the chloride ion concentration increased from about 20 mg/l to 70 mg/l. Soil samples showed no presence of chlorides and the chloride levels did not fluctuate in any of the monitor wells.

Although sodium ions can move through soil in the same way as chloride ions, they may become adsorbed on clays with high cation exchange properties. Lysimeter percolates analysed for sodium showed a removal of 40-50%, while well points and monitor wells did not vary in sodium content throughout the experiment.

Theoretically, if sodium is adsorbed on to the soil through cationic exchange, calcium should be released into the groundwater and produce an increase in water hardness. In this study, analysis for calcium carbonate on well-point and lysimeter samples did not show any significant change in hardness. Calcium determinations carried out on soil samples however, showed medium values after the first season of spraying, and after the second season the values in the high rate area jumped from 1500 mg/l to 2300 mg/l.

Magnesium, as well as being subject to the same type of reactions as calcium, also functions as a trace plant nutrient. Levels after the first season of spraying were medium for the control and low rate area and high for the high rate area. Following the second season, magnesium levels had increased in all three areas, most noteably in the low rate area, where the medium rating of 158 mg/l jumped to a high rating of 268 mg/l.

Over the span of the project, only nitrate concentration increased in the groundwater samples. However, the levels of calcium and magnesium in particular, and potassium to a lesser extent, increased in the soils which had been sprayed.

7.2 Crop Response

The use of the sewage effluent as a fertilizer was attempted on crops of corn and rye grass during the second spraying season. Both crops were planted late in the spring, developed slowly, and were killed by an early frost before reaching full maturity. The failure of the corn and rye grass to mature may have been in part due to the generally poor growing season in 1972, but may also indicate that a simple nutrient-enriched irrigation system is not sufficient for good crop response. However, no crop management procedures were put into effect and weed control, as well as fertilization, would appear to be especially important in obtaining a successful harvest.

7.3 Public Health

Well points and monitor wells were kept under intensive microbiological surveillance in order to indicate any possible ground water contamination before it reached public or municipal wells in the immediate area. Bacterial and viral pathogens were monitored to determine whether coliforms and/or bacteriophages could be used adequately to forecast contamination of groundwater or wells due to the spraying.

Monitor, municipal and house wells were all sampled at least once a month during the study and examined for fecal coliforms. All potable water wells showed no trace at any time. Well points yielded negative fecal coliform tests until October 5, 1971, when the low rate well point gave a count of 12 fecal coliforms per 100 ml. Counts of less than ten per 100 ml. occurred in all other well points until after spraying had been terminated for the winter. Within a month of the shut-down, the coliform counts returned to zero. The following spraying season, coliform counts in the well points remained at zero until September 12, when a fecal coliform count of 532 per 100 ml. was recorded in the forest well point. This could have been the result of the heavy spraying done that day on the high groundwater table area.

The counts at other well points ranged from 10 per 100 ml to 100 per 100 ml for the remaining spraying period, and well points still gave counts of 100 per 100 ml, two months after spraying had been stopped. The presence of fecal coliform bacteria in the well points indicated that contamination of the groundwater was possible, especially towards the end of the spraying season when the ground tended to become saturated.

Bacteriophages are bacterial viruses and, since they have similar physical properties would be expected to show a similar migration pattern through soil and ground water to that of human enteric viruses. In an attempt to trace such viral movements in this irrigation project, analyses for the bacteriophage of E coli B were performed.

Samples of the lagoon effluent were nearly always positive for bacteriophage. The forest well point yielded a bacteriophage isolation in the first spraying season early in November; the same well point was positive once in the second season as was the low rate well point. No positive isolations were recorded for any potable water well or for any well point not directly exposed to spraying. Contamination of the surrounding area did not apparently occur by passage of the bacteriophage through the soil.

The general lack of knowledge regarding the transfer of virus through soil and ground water can be attributed to the unavailability of an inexpensive, quantitative isolation system. In the Shelburne project, only the OPP and Municipal wells, and the lagoon effluent were monitored for human enteric viruses. The MF method was used for the potable water wells and the Moore swab technique for the lagoon effluent. All tests for human enteric viruses were negative.

Salmonellae frequently occur in raw sewage and sewage effluents, and techniques for their isolation are well described. Since they may have the ability to survive for relatively long periods even when sprayed on to land, and in view of their pathogenicity to man, this group of micro-organisms was monitored closely. All samples including those from the lagoon effluent, were negative for Salmonellae. The absence from the lagoon effluent may be a reflection of the relatively small population served by the lagoon, and the fact that this particular group are known to die out quite rapidly in the lagoon environment.

7.4 Wind Drift

Presently there are no criteria governing the distance a spray disposal project must be from the nearest public building. Viral and bacterial contaminants transferred by sewage effluent mist created during the spraying could introduce a health hazard to inhabitants of the surrounding areas, unless proper abatement procedures are followed.

Spraying operations at Shelburne were shut down on excessively windy days to avoid spreading a fine effluent mist over control areas and nearby private property. On August 11, 1971, the wind blew across the spray area from the WNW at a maximum hourly speed of 21 mph, with gusts to 30 mph* . Complaints of effluent mist being deposited on cars at the OPP Station directly downwind and approximately 400 m (1/4 mile) from the nearest corner of the spray area were received, and the spraying was immediately shut down. No further instances of wind drift occurred.

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* Figures taken from Monthly Record, Meterological Observations in Canada, August 1971, Mount Forest Weather Station.

TABLE IV

CONCENTRATION (CONC) AND PERCENT REMOVALS (% REM) OF PLANT NUTRIENTS IN LYSIMETER PERCOLATES

	NITROGEN						PHOSPHORUS				POTASSIUM	
1971	Free Ammonia (NH_3)		Total Kjeldahl		Nitrate (NO_3)		Total P		Ortho P			
	Conc	% Rem	Conc	% Rem	Conc	% Rem	Conc	% Rem	Conc	% Rem	Conc	% Rem
Effluent	3.0	--	9.2		.25	--	4.1	--	2.9	--	11.0	--
High Rate (Surface)	.01	99	2.4	74	.07	72	.16	96	.021	99	9.1	17
Low Rate (Surface)	.02	99	2.1	77	.01	96	.27	93	.081	97	5.2	53
Low Rate (120 cm)	.01	99	1.5	84	6.3	-2420	.10	98	.005	99	1.8	84
1972												
Effluent	2.2	--	10.7	--	.14	--	3.8	--	1.8	--	10.7	--
Rye Grass	.04	98	3.8	65	.10	29	.63	83	.10	94	--	--
Twitch Grass	.73	64	4.1	62	.37	-164	.57	85	.10	94	--	--

Figures in mg/l represent average values over spraying period.

Negative percentages indicate increase in concentration.

TABLE V

SOIL ANALYSIS AFTER EACH SPRAYING SEASON

1971	Phosphorus		Potassium		Magnesium		Calcium		Sodium		Chloride		pH	Salanity
	Test	Rating	Test	Rating	Test	Rating	Test	Rating	Test	Rating	Test	Rating		
Control Plot	11	L	24	L-	196	M	1700	M	80	L+	0	L	7.1	--
Low Rate Area	4	L-	60	L+	158	M	1300	M	75	L+	0	L	6.7	--
High Rate Area	4	L-	96	M	320	H	1500	M	75	L+	0	L	7.4	--
1972														
Control Plot	4	L-	40	L	326	M	1900	M	0	L	0	L	7.5	140
Low Rate Area	7	L	152	L	268	H	1700	M	0	L	0	L	7.3	120
High Rate Area	4	L-	76	M-	344	H	2300	M+	0	L	0	L	7.7	120

All Figures are in ppm except pH and Salinity (Micromhos)

8.0 SUMMARY AND CONCLUSIONS

The program at Shelburne demonstrated that spraying sewage lagoon effluent on the land is a viable zero-discharge system provided that application rates are within the chemical and physical capacities of the land available.

The relatively permeable Shelburne soil (10^{-4} cm/sec) could absorb the effluent spray at a rate of 7.6 cm/week (3.2 in/wk). At this spraying rate the highest allowable application of effluent would be 104 m^3/ha/day (9,300 IG/acre/day). This figure was calculated from the highest spraying rate applied during the project in September of 1971. During colder months of the spraying season application rates had to be reduced to allow the soil a suitable recovery period.

The soil was able to absorb nutrients from the effluent at an average of up to 95% phosphorus, 78% total Kjeldahl nitrogen and 84% potassium removal. Salts and metals in the effluent capable of percolating through the soil did not impair the quality of the ground water and had no effect on bedrock potable water wells. Calcium, magnesium and potassium levels increased in the sprayed soils.

The failure of the crops to mature was most probably caused by the lack of crop management.

The occasional presence of coliform bacteria in all well points indicates the possibility of sewage or soil bacterial migration through ground water tables. No other physical side effects of land disposal were noticed during the Shelburne study.

Weather played an important role in determining the amount of spraying carried out. Excessive rain, wind, cold weather or combinations of these, seriously impeded the scheduled spraying program.

9.0 RECOMMENDATIONS

Because effluent mist has travelled at least 400 meters, a safety zone of 800 meters (½ mile) around the perimeter of the spraying area would seem necessary if spraying is to be attempted on windy days. Planting high, fast growing trees, such as poplar, around the perimeter may also be an effective way of abating wind drift and perhaps eliminating the need for a large safety area.

For soils similar to Shelburne a minimum of 1.2 ha (3 acres) of land are needed for every 45.5 m^3 (100,000 IG) per week of effluent to be sprayed. The value of land and equipment for large permanent installations is a prime consideration.

Spray irrigation is not recommended for areas which experience frequent inclement weather. Areas subject to long frost seasons and frequent rainy and windy weather should not be considered for a spray irrigation program unless large areas of suitable land are available for a short spraying period.

When sites are selected for construction of lagoons, soils with low permeability are generally preferred while relatively permeable soils are needed for spray irrigation programs. Normally it is difficult to find two compatible areas close together.

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APPENDIX I

SPRAY VOLUMES AND MASS OF CHEMICALS APPLIED

AREA	YEAR	VOLUME	APPLIED	BOD	P	N	K	Cl
		MIC	$m^3 x 10^3$	(lb)	(lb)	**(lb)**	**(lb)**	**(lb)**
A (High Rate)	1971	1.62	7.37	675	64	168	177	1249
	1972	1.11	5.03	463	44	115	121	857
	Total	2.73	12.40	1138	108	283	298	2106
B (Low Rate)	1971	1.24	5.65	515	49	128	135	954
	1972	1.13	5.15	472	45	117	124	874
	Total	2.37	10.80	987	94	245	259	1828
C (Treed)	1971	.28	1.28	116	11	29	30	215
	1972	.10	.46	42	4	10	11	78
	Total	.38	1.74	158	15	39	41	293
	TOTAL OVERALL	5.48	24.94	2283	217	567	598	4227

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